CLAIMS

1. A method of providing a correcting for a slave instrument, of the kind measuring properties of an object by exposing the object to electromagnetic radiation, in particular X-rays, in at least two spectral ranges and obtaining one or more object responses thereto, the responses being based on detecting attenuation and/or reflection and/or scatter of the electromagnetic radiation in/from the object by use of one or more detectors and are obtained in a form where they express properties either directly or via a transformation, said method of correcting comprising

- obtaining, for a plurality of stable objects, a set of responses comprising one or more pair of related responses (Q_{low}^{s} and Q_{high}^{s}) representing measurements in the at least two spectral ranges performed with the slave instrument and a set of responses, comprising one or more pair of related responses (Q_{low}^{m} and Q_{high}^{m}) representing measurements in the at least two spectral ranges performed with a master instrument,
    - to each pair of related responses (Q_{low}^{s} and Q_{high}^{s}) of the slave instrument corresponds a pair of related responses (Q_{low}^{m} and Q_{high}^{m}) of the master instrument,
    - and to each element in each pair of responses (Q_{low}^{s} and Q_{high}^{s}) of the slave instrument corresponds an element in the corresponding pair of responses (Q_{low}^{m} and Q_{high}^{m}) of the master instrument;
- determining based on the sets of responses a correcting function being a functional relationship between a ratio of related responses of the master instrument and a sum of a plurality of terms, each term being a product of a correcting coefficient (B_i) and powers of related responses (Q_{low}^{s} and Q_{high}^{s}) of the slave instrument, wherein each response being raised to a power being a positive or negative real number, or zero, thereby determining a first set of correcting coefficients (B_0; B_1; B_2 .....) being multiplied on each of the terms;

and

- storing the first set of correcting coefficients (B_0; B_1; B_2 .....) in memory means included in or adapted for communication with data processing means included in or adapted for communication with the slave instrument.

2. A method according to claim 1, wherein, initially, at a manufactures site

- measuring the plurality of stable objects on a master instrument, thereby obtaining the set of responses representing measurements performed with the master instrument (Q_{low}^{m} and Q_{high}^{m}),
- storing the set of responses (Q_{low}^{m} and Q_{high}^{m}) as a set of constant values in memory means, which is accessible from a slave instrument, when measuring the corresponding stable objects on a slave instrument in order to carry out a method of providing a correcting according to claim 1.

3. A method according to claim 2, wherein the set of responses measured by the master instrument is stored in memory means included in or adapted for communication with data processing means included in or adapted for communication with the slave instrument.

4. A method according to claim 1, 2 or 3, wherein the determination of the correcting function being based on a regression method.

5. A method according to claim 4, wherein the regression method is selected from the group consisting of principal component regression, multiple linear regression, partial least squares regression, and artificial neural networks.

6. A method according to any of the preceding claims, wherein the correcting function comprising a plurality of terms of the following form $Q_{low}^{n1} * Q_{high}^{m1}$ wherein n1 and m2 are real numbers and/or integers, and n1 is positive.

7. A method according to claim 6, wherein the correcting function comprising at least three of the following terms: Q_{low}, Q_{high}, Q_{low}^{2}, Q_{high}^{2} and Q_{low} / Q_{high}.

8. A method according to claim 6, wherein the correcting function comprising at least three of the following terms: $Q_{low} * Q_{high}$; $Q_{low}^{2} * Q_{high}$; $Q_{low} * Q_{high}^{2}$; Q_{low}^{2} / Q_{high}; Q_{low} / Q_{high}^{2}; $Q_{low}^{2} / Q_{high}^{2}$; $Q_{low}^{2} / Q_{high}^{2}$.

9. A method according to any of the preceding claims, wherein the correcting function is of the form:

$$\frac{Q_{low}^{m}}{Q_{high}^{m}} = B_1 Q_{low}^{s} + B_2 Q_{high}^{s} + B_3 {Q_{low}^{s}}^2 + B_4 {Q_{high}^{s}}^2 + B_5 Q_{low}^{s} Q_{high}^{s} + B_6 {Q_{low}^{s}}^2 Q_{high}^{s} + B_7 Q_{low}^{s} {Q_{high}^{s}}^2$$

$$+ B_8 \frac{Q_{low}^{s}}{Q_{high}^{s}} + B_9 \frac{{Q_{low}^{s}}^2}{Q_{high}^{s}} + B_{10} \frac{Q_{low}^{s}}{{Q_{high}^{s}}^2} + B_{11} \left[\frac{Q_{low}^{s}}{Q_{high}^{s}}\right]^2 + B_0$$

10. A method according to any of the preceding claims, further comprising determining based on the sets of responses a further correcting function being a functional relationship between responses of the slave instrument (Q_{low}^{s} or Q_{high}^{s}) and related responses (Q_{low}^{m} or Q_{high}^{m}) of the master instrument, thereby determining a second set of correcting coefficients (α; β).

11. A method according to claim 10, wherein the further correcting function being a functional relationship between a high energy response of the slave instrument (Q_{high}^{s}) and the related high energy response (Q_{high}^{m}) of the master instrument.

12. A method according to claim 11, wherein the further correcting function is determined by use of univariate linear regression.

13. A method according to claim 12, wherein the further correcting function being of the form $Q_{high}^{m} = \alpha \cdot Q_{high}^{s} + \beta$.

14. A method according to any of the preceding claims, wherein the set of responses for the master instrument and the set of responses for the slave instrument each comprise one pair of related responses for each stable object comprised in the plurality of stable objects.

15. A method according to any of the preceding claims, wherein the related responses are obtained based on measuring on objects being conveyed.

16. A method according to any of the preceding claims, wherein each of the responses (Q) is an intensity (I), if necessary corrected with respect to dark current of the detectors.

17. A method according to any of the claims 1-15, wherein each of the responses is a transmittance (T) being derived from intensity as a ratio between intensity resulting from measuring on an object and reference intensity.

18. A method according to any of the claims 1-15, wherein each of responses is an absorbance being defined as the negative logarithm to a transmittance (A=-log(T)) such as logarithm base 10, the natural logarithm, or any other logarithmic function.

19. A method according to any of the claims 1-15, wherein the responses for both the master and the slave instruments are absorbances being determined by calculating

$$A_{low} = -\log_{10}\left[\frac{I_{sample}(low) - I_{dark}(low)}{I_{air}(low) - I_{dark}(low)}\right] \text{ and}$$

$$A_{high} = -\log_{10}\left[\frac{I_{sample}(high) - I_{dark}(high)}{I_{air}(high) - I_{dark}(high)}\right]$$

wherein the intensities (I) are obtained in a measuring region of the master instrument respectively the slave instrument by:

- exposing the object in the measuring region to low and high X-ray energies and detecting with detectors the intensities $I_{sample}(low)$ and $I_{sample}(high)$ respectively
- detecting the intensities $I_{dark}(low)$ and $I_{dark}(high)$ from said detectors when no radiation reaches them;

and

- exposing said detectors to the low and high X-ray energies signals when no object is present in the measuring region and detecting $I_{air}(low)$ and $I_{air}(high)$.

20. A method according to any of the claims 1-15, wherein each of the responses is a reflectance (R) expressing the reflectance from the surface of the object.

21. A method according to claim 19, wherein the reflectance (R) is linearized, preferably using the Kubelka-Munk transform (K/S=(1-R)/2R).

22. A method of correcting responses representing measurements performed with a slave instrument, said method comprising for an object

- determining based on measurements with the slave instrument a pair of related responses (Q_{low}^{s} and Q_{high}^{s}),
- determining the ratio $[Q_{low}/ Q_{high}]^{corr}$ by a correcting function being a functional relationship between a ratio of related responses of the master instrument and a

sum of a plurality of terms, each term being a product of a correcting coefficient (B_i) and powers of related responses (Q_{low}^s and Q_{high}^s) of the slave instrument wherein each response being raised to a power being a positive or negative real number, or zero,

- providing Q_{high}^{corr} either by assuming that Q_{high}^{corr} is substantially equal to Q_{high}^s or by use of a further correcting function correlating Q_{high}^{corr} with Q_{high}^s ;

and

- calculating Q_{low}^{corr} as Q_{high}^{corr} * $[Q_{low}/ Q_{high}]^{corr}$;

thereby providing a set of corrected responses.

23 A method according to claim 22, wherein the further correcting function being of the form $Q_{high}^{corr} = \alpha \cdot Q_{high}^s + \beta$.

24. A method according to claim 22 or 23, wherein the correcting function comprises terms of the following form $Q_{low}^{n1} * Q_{high}^{m1}$, wherein n1 and m2 are real numbers and/or integers, and wherein n1 is positive.

25. A method according to any of the claims 22-24, wherein the correcting function comprises at least three of the following terms: Q_{low}, Q_{high}, Q_{low}^2, Q_{high}^2 and Q_{low} / Q_{high} .

26. A method according to any of the claims 22-25, wherein the correcting function comprising at least three of the following terms: $Q_{low} \cdot Q_{high}$; $Q_{low}^2 * Q_{high}$; $Q_{low} * Q_{high}^2$; Q_{low}^2 / Q_{high}; Q_{low} / Q_{high}^2; Q_{low}^2 / Q_{high}^2; Q_{low}^2 / Q_{high}^2.

27. A method according to any of the claims 22-26, wherein the correcting function is of the form:

$$\left(\frac{Q_{low}}{Q_{high}}\right)^{corr} = B_1 Q_{low}^s + B_2 Q_{high}^s + B_3 Q_{low}^{s\ 2} + B_4 Q_{high}^{s\ 2} + B_5 Q_{low}^s Q_{high}^s + B_6 Q_{low}^{s\ 2} Q_{high}^s + B_7 Q_{low}^s Q_{high}^{s\ 2}$$

$$+ B_8 \frac{Q_{low}^s}{Q_{high}^s} + B_9 \frac{Q_{low}^{s\ 2}}{Q_{high}^s} + B_{10} \frac{Q_{low}^s}{Q_{high}^{s\ 2}} + B_{11} \left[\frac{Q_{low}^s}{Q_{high}^s}\right]^2 + B_0$$

28. A method according to any of the claims 22-27, wherein each of the responses (Q) is an intensity (I), if necessary corrected with respect to dark current of the detectors.

29. A method according to any of the claims 22-27, wherein each of the responses is a transmittance (T) being derived from intensity as a ratio between intensity resulting from measuring on an object and a reference intensity.

30. A method according to any of the claims 22-27, wherein each of responses is an absorbance being defined as the negative logarithm to a transmittance (A=-log(T)) such as logarithm base 10, the natural logarithm, or any other logarithmic function.

31. A method according to any of the claims 22-27, wherein the responses are absorbances being determined by calculating

$$A_{low} = -\log_{10}\left[\frac{I_{sample}(low) - I_{dark}(low)}{I_{air}(low) - I_{dark}(low)}\right] \text{ and}$$

$$A_{high} = -\log_{10}\left[\frac{I_{sample}(high) - I_{dark}(high)}{I_{air}(high) - I_{dark}(high)}\right]$$

wherein the intensities (I) are obtained in a measuring region of the slave instrument by:

- exposing an object in the measuring region to low and high X-ray energies and detecting with detectors the intensities $I_{sample}(low)$ and $I_{sample}(high)$ respectively
- detecting with the detectors the intensities $I_{dark}(low)$ and $I_{dark}(high)$ from said detectors when no radiation reaches them;

and

- exposing said detectors to the low and high X-ray energies signals when no object is present in the measuring region and detecting $I_{air}(low)$ and $I_{air}(high)$.

32. A method according to any of the claims 22-27, wherein each of the responses is a reflectance (R) expressing the reflectance from the surface of the object.

33. A method according to claim 32, wherein the reflectance (R) is linearized, preferably using the Kubelka-Munk transform (K/S=(1-R)/2R).

34. A method according to any of the preceding claims, wherein the correcting function and the further correcting function being determined by the method according to any of the claims 1-21.

35. A method of determining a physical quantity for an object by a slave instrument, the method comprising

- determining for the object corrected high and low energy responses (Q_{high}^{corr} and Q_{low}^{corr}) by utilizing the method according to any of the claims 22-34,
- determining the physical quantity by applying on said corrected responses a calibrated functional relationship between Q_{high}^{corr} and Q_{low}^{corr} and a physical quantity.

36. A method according to claim 35, wherein the calibrated functional relationship being a functional relationship between a physical quantity and a sum of a plurality of terms, each term being a product of a calibration coefficient (B_i) and powers of related responses (Q_{low}^{s} and Q_{high}^{s}), wherein each response being raised to a power being a positive or negative real number, or zero.

37. A method according to claim 36, wherein the calibrated functional relationship comprises terms being of the form: $Q_{low}^{n1} * Q_{high}^{m1}$ wherein n1 and m2 are real numbers and/or integers, and wherein n1 is positive, such as comprises terms being of the form: Q_{low}, Q_{high}, Q_{low}^{2}, Q_{high}^{2} and Q_{low} / Q_{high}, preferably comprises terms of the form: $Q_{low} \cdot Q_{high}$; $Q_{low}^{2} * Q_{high}$; $Q_{low} * Q_{high}^{2}$; Q_{low}^{2} / Q_{high}; Q_{low} / Q_{high}^{2}; $Q_{low}^{2} / Q_{high}^{2}$; $Q_{low}^{2} / Q_{high}^{2}$.

38. A method according to claim 37, wherein the calibrated functional relationship is of the form:

$$F(Q) = B_1 Q_{low}^{s} + B_2 Q_{high}^{s} + B_3 {Q_{low}^{s}}^2 + B_4 {Q_{high}^{s}}^2 + B_5 Q_{low}^{s} Q_{high}^{s} + B_6 {Q_{low}^{s}}^2 Q_{high}^{s} + B_7 Q_{low}^{s} {Q_{high}^{s}}^2 + B_8 \frac{Q_{low}^{s}}{Q_{high}^{s}} + B_9 \frac{{Q_{low}^{s}}^2}{Q_{high}^{s}} + B_{10} \frac{Q_{low}^{s}}{{Q_{high}^{s}}^2} + B_{11} \left[\frac{Q_{low}^{s}}{Q_{high}^{s}} \right]^2 + B_0$$

39. A method according to any of the claims 35-38, wherein the calibration model is obtained by exposing the master instrument to a plurality of well-defined objects.

40. A method according to claim 39, wherein the well defined objects are defined in the sense that the physical properties of the object have been established by a chemical process, such as an officially recognized reference method for the determination of the requested physical property.

41. A method according to any of the claims 35-40, wherein each of the responses (Q) is either:

- an intensity (I), if necessary corrected with respect to dark current of the detectors;
- a transmittance (T) being derived from intensity as a ratio between intensity resulting from measuring on an object and a reference intensity;
- an absorbance being defined as the negative logarithm to a transmittance (A=-log(T)) such as logarithm base 10, the natural logarithm, or any other logarithmic function;

or

- a reflectance (R) expressing the reflectance from the surface of the object, the reflectance (R) is preferably linearized using the Kubelka-Munk transform (K/S=(1-R)/2R).

42. A method according to claim 41, wherein, in case the responses are absorbances, the absorbances being determined by calculating

$$A_{low} = -\log_{10}\left[\frac{I_{sample}(low) - I_{dark}(low)}{I_{air}(low) - I_{dark}(low)}\right] \text{ and}$$

$$A_{high} = -\log_{10}\left[\frac{I_{sample}(high) - I_{dark}(high)}{I_{air}(high) - I_{dark}(high)}\right]$$

wherein the intensities (I) are obtained in a measuring region of the slave instrument by:

- exposing an object in the measuring region to low and high X-ray energies and detecting with detectors the intensities $I_{sample}(low)$ and $I_{sample}(high)$ respectively
- detecting with the detectors the intensities $I_{dark}(low)$ and $I_{dark}(high)$ from said detectors when no radiation reaches them;

and

- exposing said detectors to the low and high X-ray energies signals when no object is present in the measuring region and detecting $I_{air}(low)$ and $I_{air}(high)$.

43. A method of using a slave instrument for determining physical quantities, such as the fat content, of an object, such as food or feed, by use of dual X-ray radiation, said method comprising:

- scanning substantially all or all of the object by X-ray beams having at least two energy levels, including a low level and a level being higher relatively thereto,
- detecting the X-ray beams having passed through the object for a plurality of areas of the object;

- for each area of the object
  - determining the object's response (Q_{low}) at the low energy level and the object's response (Q_{high}) at the high energy level,
  - correcting the responses so determined by utilising the correcting method according to any of the claims 22-34,

  and

  - determining the physical property by utilizing the method according to claims 35-42.

44. A data processing system for providing a correction for a slave instrument, said system utilizes sets of responses being based on detecting attenuation and/or reflection and/or scatter of electromagnetic radiation, in particular X-ray, in/from a object exposed to said electromagnetic radiation in at least two spectral ranges, the set of responses comprises one or more pair of related responses (Q_{low}^s and Q_{high}^s) representing measurements performed with a slave instrument and a set of responses comprising one or more pair of related responses (Q_{low}^m and Q_{high}^m) representing measurements performed with a master instrument, said responses being obtained for a plurality of stable objects and

- to each pair of related responses of the slave instrument corresponds a pair of related responses of the master instrument,
- and to each element in each pair of responses of the slave instrument corresponds an element in the corresponding pair of responses of the master instrument;

said data processing system comprising

- means for accessing memory means wherein the responses (Q_{low}^m and Q_{high}^m) of the master instrument and/or the responses (Q_{low}^s and Q_{high}^s) of the slave instrument are stored,
- means, such as processor means, for determining based on the sets of responses a correcting function being a functional relationship between a ratio of related responses of the master instrument and a sum of a plurality of terms, each term being a product of a correcting coefficient (B_i) and powers of related responses (Q_{low}^s and Q_{high}^s) of the slave instrument wherein each response being raised to a power being a positive or negative real number, or zero, thereby determining a first set of correcting coefficients (B_0; B_1; B_2 .....) being multiplied on each of the terms,
- means for storing the first set of correction coefficients (B_0; B_1; B_2 .....).

45. A data processing system according to claim 44, further comprising means for determining a further correcting function being a functional relationship between a high energy response of the slave instrument (Q_{high}^{s}) and related high energy response (Q_{high}^{m}) of the master instrument, thereby determining a second set of correcting coefficients (α; β).

46. A data processing system according to claim 44 or 45, wherein each of the responses (Q) is either:

- an intensity (I), if necessary corrected with respect to dark current of the detectors;
- a transmittance (T) being derived from intensity as a ratio between intensity resulting from measuring on an object and reference intensity;
- an absorbance being defined as the negative logarithm to a transmittance (A=-log(T)) such as logarithm base 10, the natural logarithm, or any other logarithmic function;

or

- a reflectance (R) expressing the reflectance from the surface of the object, the reflectance (R) is preferably linearized using the Kubelka-Munk transform (K/S=(1-R)/2R).

47. A data processing system according to claim 46, wherein, in case the responses are absorbances, the absorbances being determined by calculating

$$A_{low} = -\log_{10}\left[\frac{I_{sample}(low) - I_{dark}(low)}{I_{air}(low) - I_{dark}(low)}\right]$$ and

$$A_{high} = -\log_{10}\left[\frac{I_{sample}(high) - I_{dark}(high)}{I_{air}(high) - I_{dark}(high)}\right]$$

wherein the intensities (I) are obtained in a measuring region of the slave instrument by:

- exposing an object in the measuring region to low and high X-ray energies and detecting with detectors the intensities $I_{sample}(low)$ and $I_{sample}(high)$ respectively
- detecting with the detectors the intensities $I_{dark}(low)$ and $I_{dark}(high)$ from said detectors when no radiation reaches them;

and

- exposing said detectors to the low and high X-ray energies signals when no object is present in the measuring region and detecting $I_{air}(low)$ and $I_{air}(high)$.

48. A correcting system comprising a slave instrument for obtaining responses and a data processing system for correcting the responses, the responses representing measurement performed with the slave instruments and the responses being based on detecting by the slave instrument attenuation and/or reflection and/or scatter of electromagnetic radiation, in particular X-ray, in/from a object exposed to said electromagnetic radiation in at least two spectral ranges, the set of responses comprises one or more pair of related responses (Q_{low}^{s} and Q_{high}^{s}), said correcting system comprises

- processor means for determining the one or more pair of related responses (Q_{low}^{s} and Q_{high}^{s}) based on measurement on an object with the slave instrument,
- means comprising processor means adapted to perform a correction of responses by utilizing a correcting according to any of the claims 22-35; said processor means comprises
- means for accessing memory means storing a first set of correction coefficients (B_0; B_1; B_2 .....)
- processor means for determining the ratio $[Q_{low}/ Q_{high}]^{corr}$ by the correcting function;
- processor means for determining the corrected high energy response Q_{high}^{corr} by the further correcting function;

and

- processor means for determining the corrected low energy response Q_{low}^{corr} by multiplying $[Q_{low}/ Q_{high}]^{corr}$ by Q_{high}^{corr}.

49. A system according to claim 48, wherein each of the responses (Q) is either:

- an intensity (I), if necessary corrected with respect to dark current of the detectors;
- a transmittance (T) being derived from intensity as a ratio between intensity resulting from measuring on an object and reference intensity;
- an absorbance being defined as the negative logarithm to a transmittance (A=-log(T)) such as logarithm base 10, the natural logarithm, or any other logarithmic function;

or

- a reflectance (R) expressing the reflectance from the surface of the object, the reflectance (R) is preferably linearized using the Kubelka-Munk transform (K/S=(1-R)/2R).

50. A system according to any of the claims 44-49, further comprising storage means wherein a set of responses ($Q_{low}{}^{m}$ and $Q_{high}{}^{m}$) for a set of stable objects measured on a master instrument are stored and /or storage means wherein the first set of correction coefficients (B_0; B_1; B_2 .....) and/or the further correcting function is stored.

51. A dual X-ray instrument comprising a system according to any of the claims 44-50 adapted to carry out a method according to any of the claims 1-35.

52. A set comprising one or more stable objects for, or used during, carrying out a method according to any of the claims 1-21, each object being characterized by being composed by at least two different chemical compositions which are substantially stable and each stable object is having response, such as absorbance, properties which are similar to the response, such as absorbance, properties of an object subjected to the method according to any of the claims 22-35.

53. A set of stable objects according to claim 52, wherein for each of the stable object a first member of the at least two different chemical compositions is one having X-ray response properties, such as absorbance properties, similar to adipose tissue, and a second member of the at least two different chemical compositions is one having X-ray response, such as absorbance, properties similar to muscle tissue.

54. A set of stable objects according to claims 52 or 53, comprising a plurality of stable objects have varying thickness and/or areal density.

55. A set of stable objects according to claim 54, wherein the plurality of stable objects being integrated into a single stepped item.

56. A set of stable objects according to any of the claims 52-55, wherein each object comprised in the set of objects is stable in the sense that the X-ray response, such as absorption, properties of the object does not change more than 0.1 %, such as no more

than 0.01 %, such as no more than.0,001%..within at least 10 days, such as at least 1 month, preferably at least 1 year.

57. A plurality of stable objects according to any of the claims 52-56, wherein the number of stable objects in the set of stable objects are at least 8, such as at least 12, preferably at least 15, or even at least 20, such as at least 26.